Aug. 26, 1969 H. R ANDERSON ETAL 3,462,949

NOISE REDUCING ENCLOSURE FOR A GAS TURBINE ENGINE

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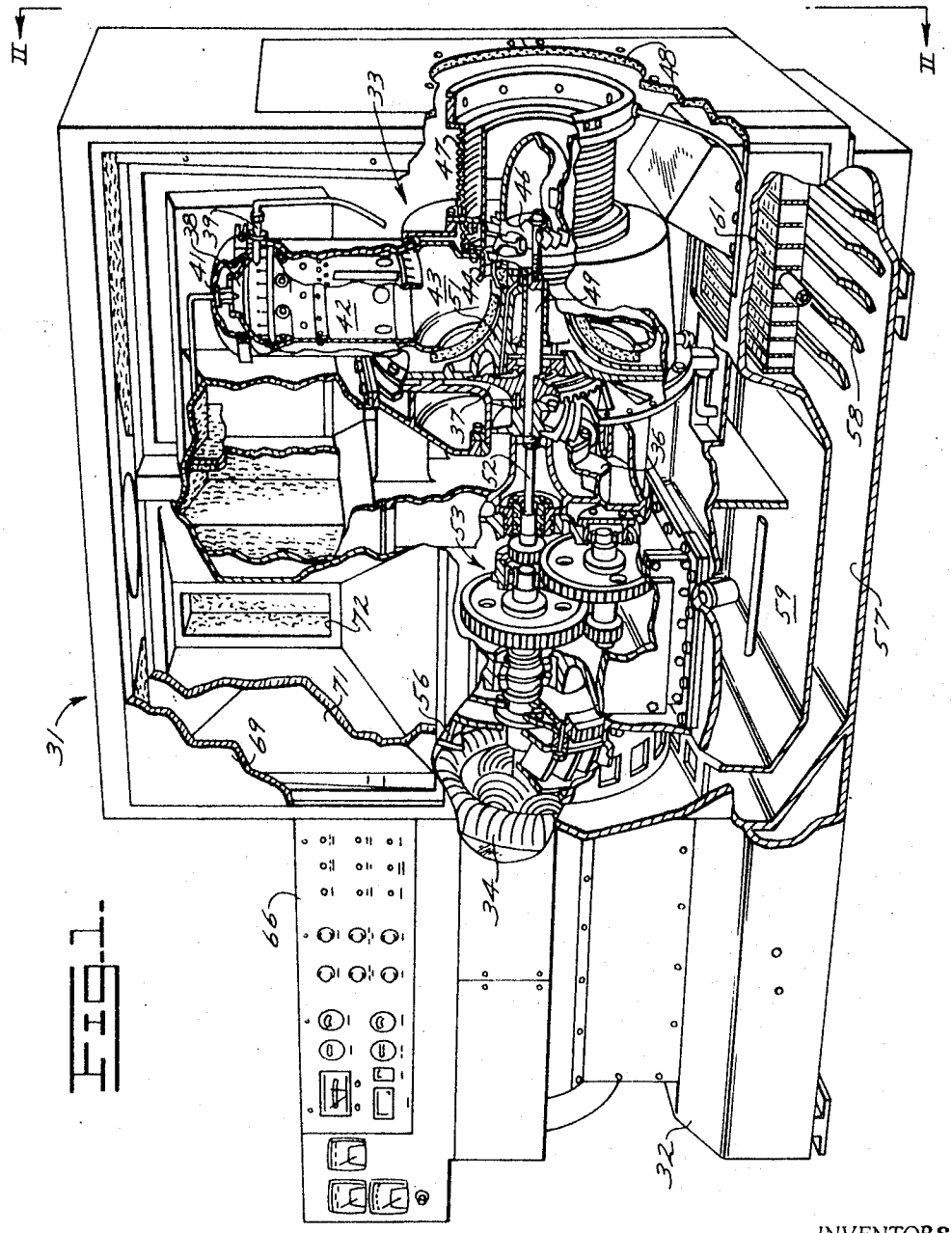


Fig. 1

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Fig. 2.

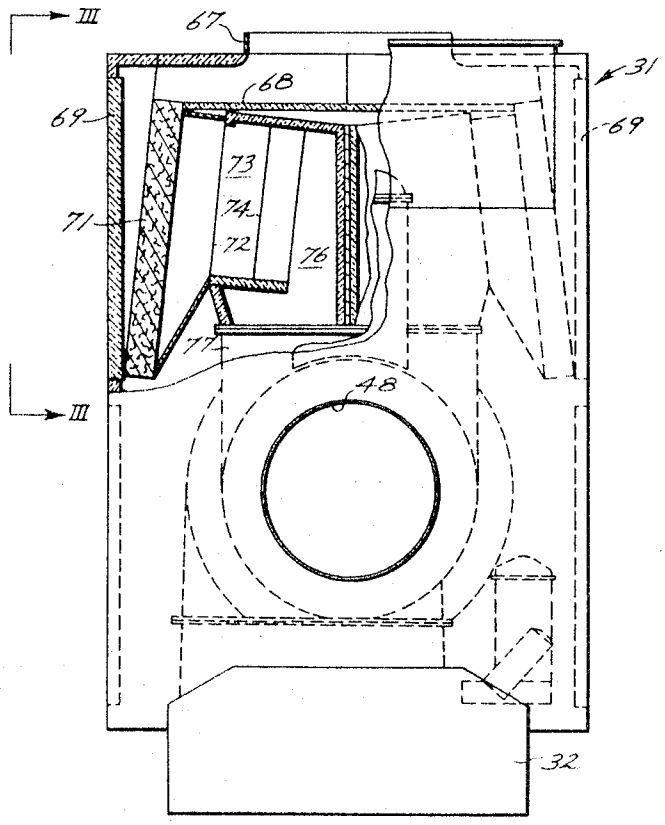
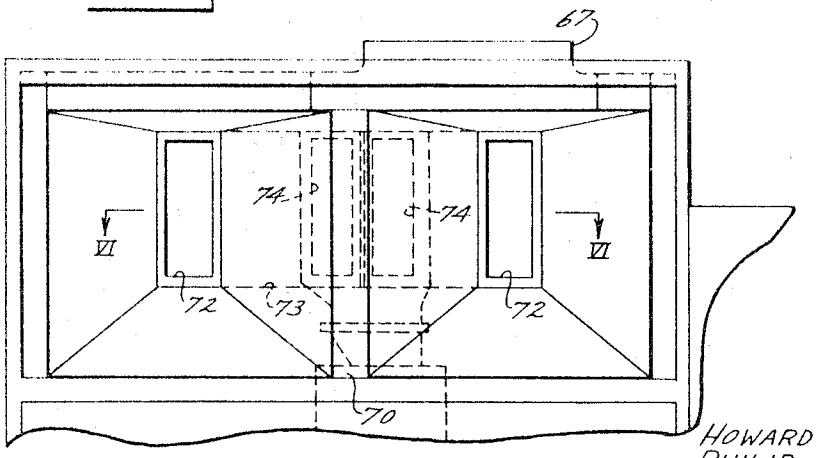


Fig. 3.



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Fig. 5.

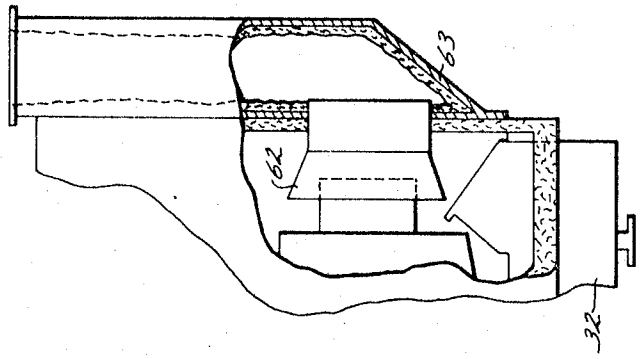
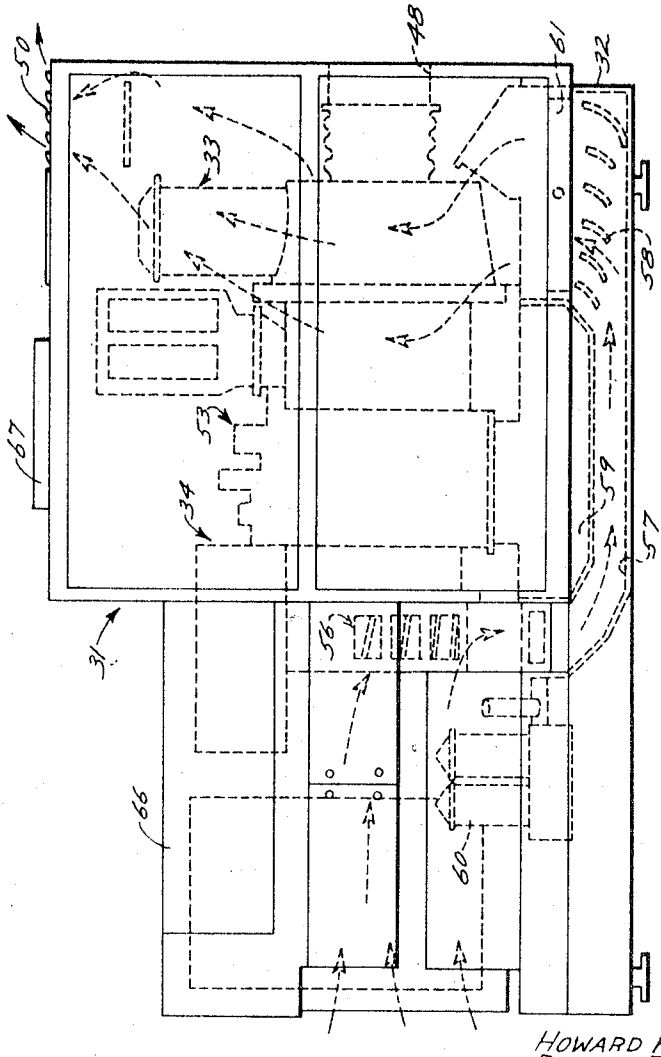


Fig. 4.



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Fig. 20.

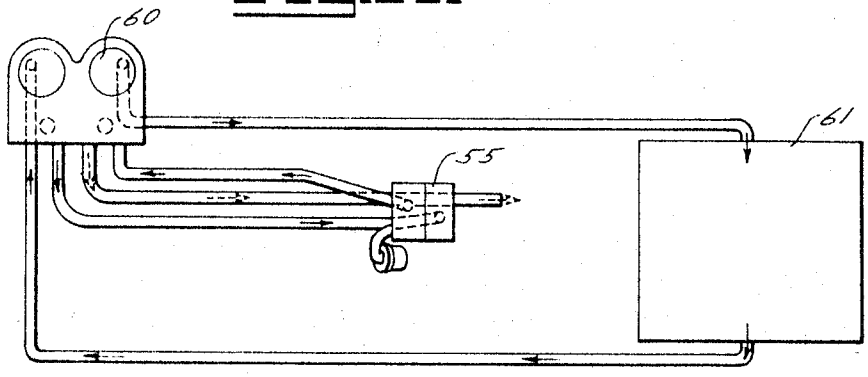


Fig. 21.

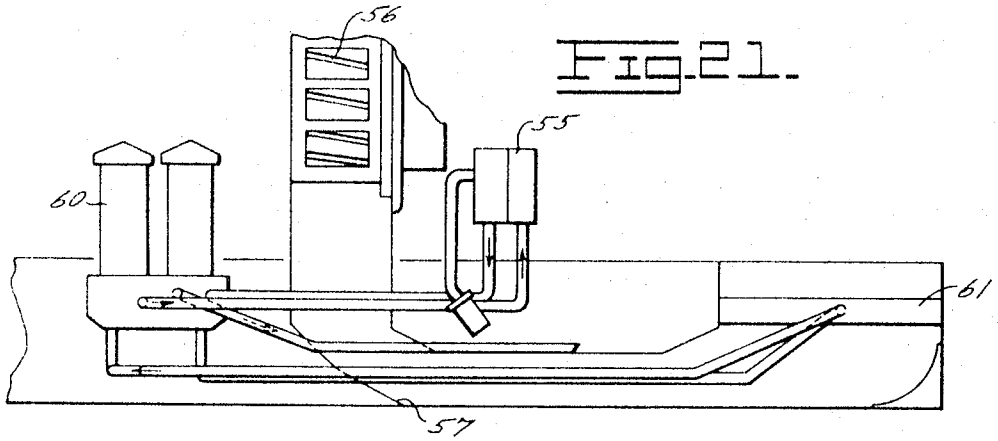
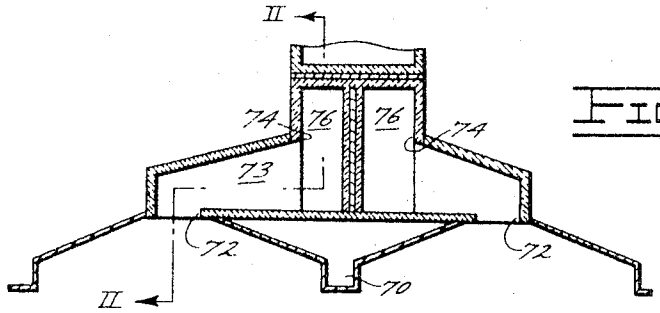


Fig. 6.



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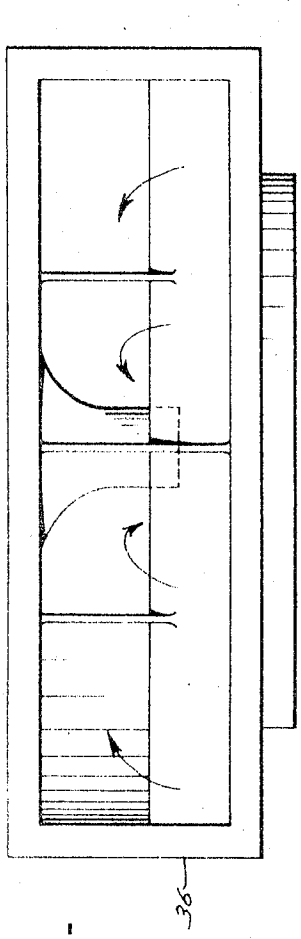


FIG. 9.

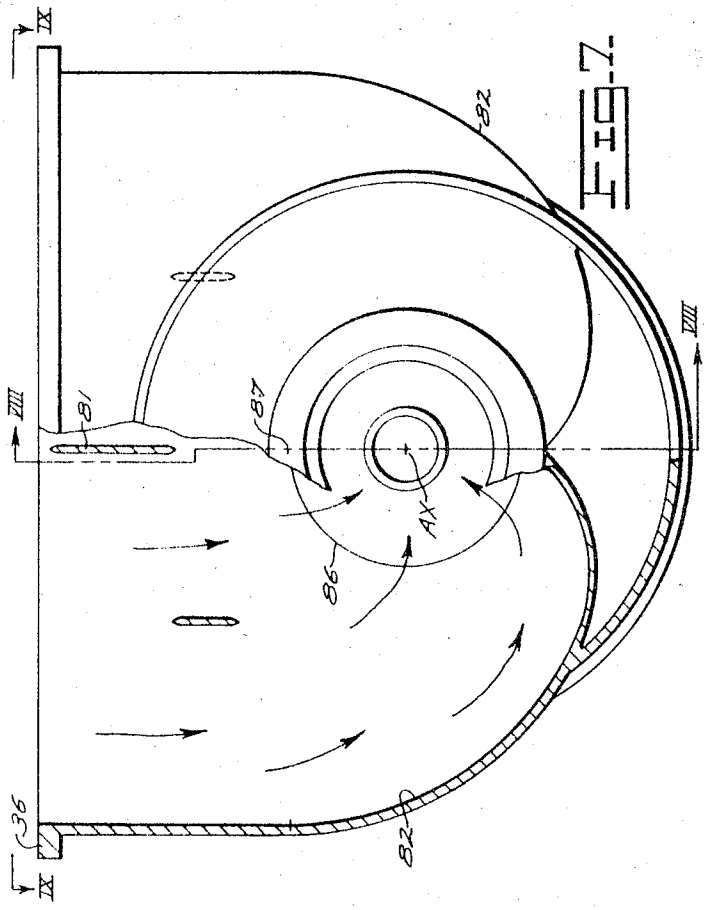


FIG. 7.

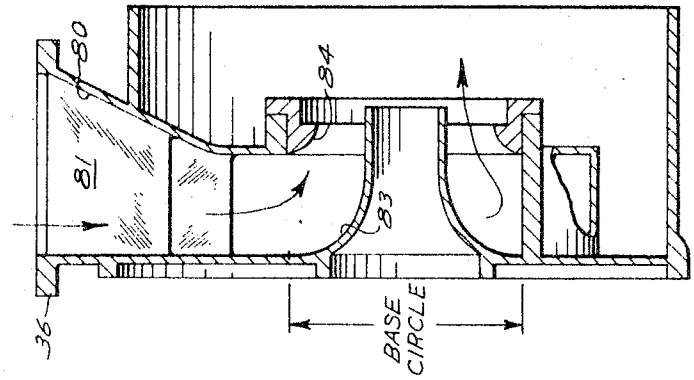


FIG. 8.

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Fig. 10.

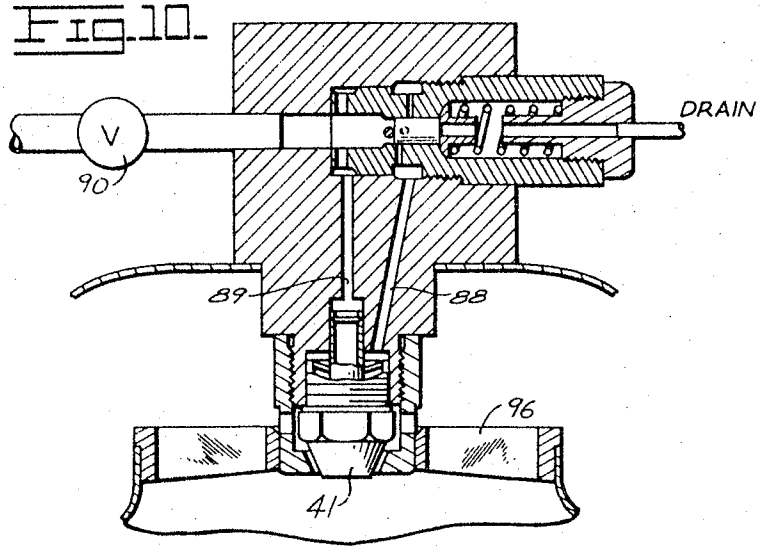


Fig. 11.

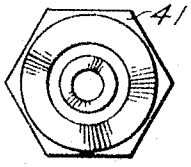


Fig. 12.

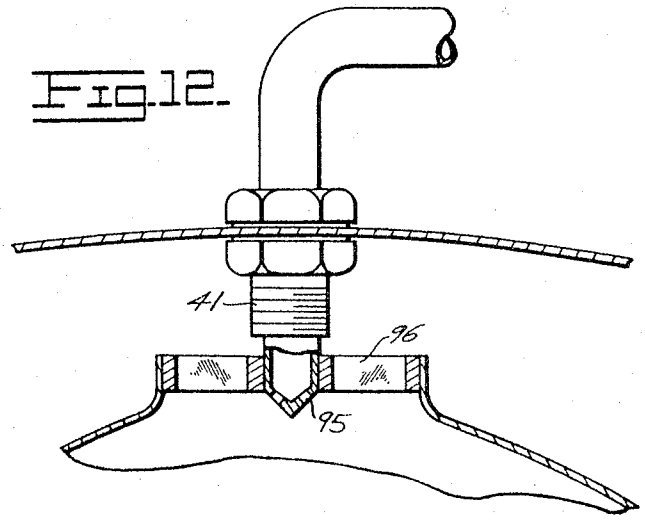
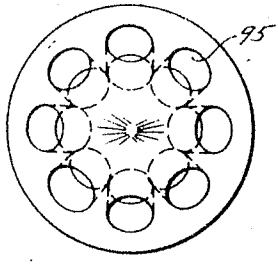


Fig. 13.



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Fig. 14.

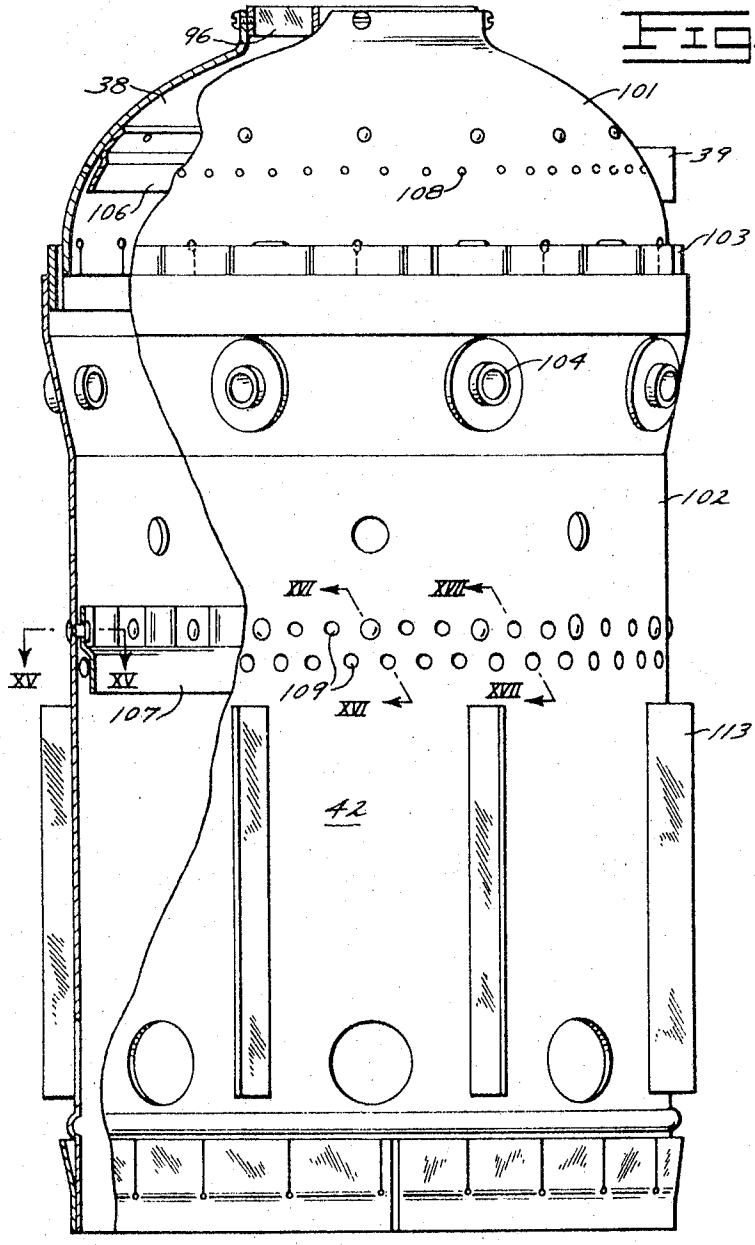


Fig. 16.

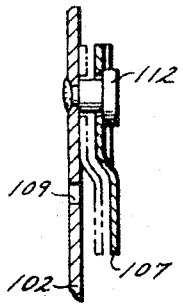


Fig. 17.

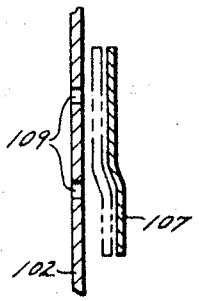
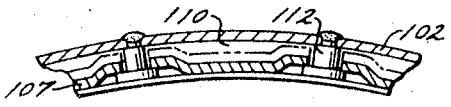


Fig. 15.



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Fig. 1A.

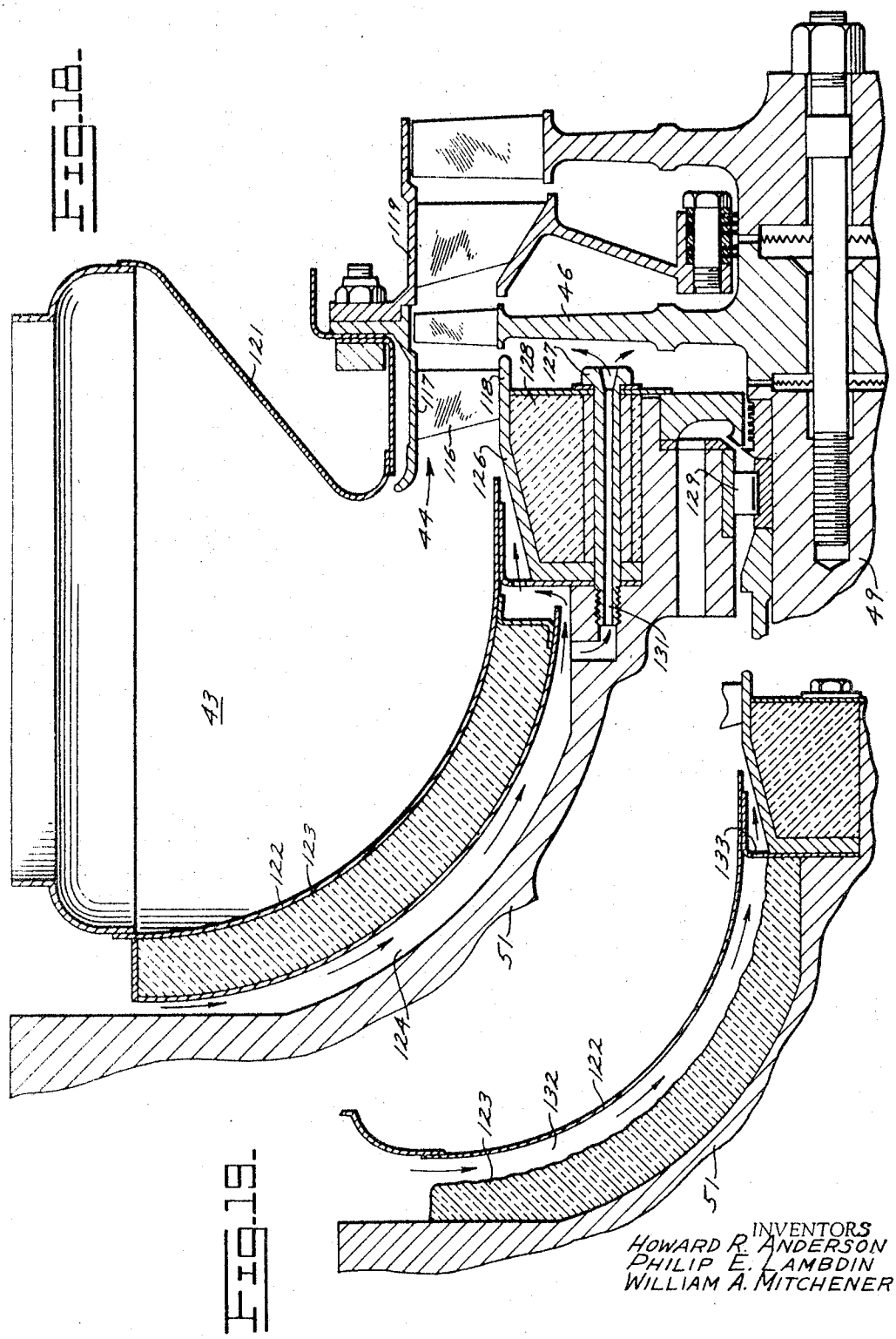


Fig. 1B.

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United States Patent Office 3,462,949 Patented Aug. 26, 1969

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NOISE REDUCING ENCLOSURE FOR A GAS TURBINE ENGINE

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Original application Sept. 13, 1965, Ser. No. 486,818, now Patent No. 3,418,485, dated Dec. 24, 1968. Divided and this application July 22, 1968, Ser. No. 763,450
Int. Cl. F02c 7/20, 7/24; F04b 39/12
U.S. Cl. 60—39.31 3 Claims

ABSTRACT OF THE DISCLOSURE

An enclosure for a gas turbine engine comprising a silencer for the engine's compressor and a specially configured compressor inlet housing to provide uniform flow free of turbulence or separation. The enclosure comprises inlet duct means for turning the incoming air through a plurality of right-angle bends thus silencing any compressor noise.

This is a division of application Ser. No. 486,818, filed Sept. 13, 1965, now Patent No. 3,418,485.

This invention relates to gas turbine engines and particularly to an integrated enclosure and mounting arrangement for a gas turbine engine and electric generator set.

The industrial gas turbine engine of the present invention is a self-contained engine package which incorporates a rigid base, all necessary ducting for silencing and filtering the engine air, and all the ducting required for cooling and ventilating as an integral part of the package. The exhaust gas ducting and all the operating controls for the engine and the generator are also included as a part of the package.

The rigid and integrally formed base facilitates transport of the engine package and eliminates the need for attachment of the engine and generator to an auxiliary mounting base when the engine is installed.

In many installations, such as roof-top installations, where heat recovery from the exhaust gases is not desired and the exhaust gases can be ventilated directly to atmosphere, the self-contained enclosure of the present invention eliminates practically all installation procedures except for attachment of fuel lines and power lines for the generator. Such highly simplified and minimum installation requirements are a primary object of the present invention.

It is an important object of the present invention to so construct the enclosure as to maintain design control of the intake air and filtering system and also the oil cooling and filtering system, rather than leaving such design in the hands of the person or persons installing the engine.

It is another important object of the present invention to incorporate cooling air ducting in the enclosure, and specifically within the base, in a manner such that the blower for the generator can be used to circulate all the cooling air needed to cool both the generator and the lubricating oil for the gas turbine engine. This object is accomplished by mounting the heat exchanger for the lubricating oil within the base and employing highly efficient ducting for circulating the cooling air from the generator to the heat exchanger.

A silencer for silencing the compressor noise is built into the inlet air ducting of the enclosure, and all of the required filtering of the inlet air is done within the enclosure. Thus, no auxiliary inlet air ducting is required to silence the compressor or to filter the incoming air.

The gas turbine engine of the present invention incorporates a specially configured inlet housing for the compressor which is effective to take the air from the inlet ducting of the enclosure and to introduce the air about the entire circumference of the compressor inlet with a highly uniform flow substantially free of turbulence or separation. The inlet housing achieves this function while retaining axial and radial compactness.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments of the present invention and the principles thereof and what are now considered to be the best modes contemplated for applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

In the drawings:

FIG. 1 is a perspective view, broken away in parts to show details of construction, of an enclosure for a gas turbine engine and electric generator set constructed in accordance with one embodiment of the present invention;

FIG. 2 is an end elevation view, taken along the line and in the direction indicated by the arrows **2—2** in FIG. 1 (and partly broken away along the line and in the direction indicated by the arrows **2—2** in FIG. 6) of the enclosure shown in FIG. 1;

FIG. 3 is a fragmentary side elevation view taken along the line and in the direction indicated by the arrows **3—3** of FIG. 2;

FIG. 4 is a side elevation view of the enclosure shown in FIG. 1;

FIG. 5 is a fragmentary side elevation view of a modified exhaust gas ducting arrangement in which the cooling and ventilating air is introduced into the exhaust gases to aspirate the flow of the cooling and ventilating air;

FIG. 6 is a fragmentary plan view taken along the line and in the direction indicated by the arrows **6—6** in FIG. 3;

FIG. 7 is an end elevation view of the air inlet housing for the compressor end of the gas turbine engine of the enclosure shown in FIG. 1;

FIG. 8 is an elevation view taken along the line and in the direction indicated by the arrows **8—8** in FIG. 7;

FIG. 9 is a plan view taken along the line and in the direction indicated by the arrows **9—9** of FIG. 7;

FIG. 10 is an elevation view through a cross section of a flow divider and fuel nozzle for liquid fuel;

FIG. 11 is an end view of the fuel nozzle shown in FIG. 10;

FIG. 12 is an elevation view through a cross section of a fuel nozzle for gaseous fuel;

FIG. 13 is an enlarged end view of the fuel nozzle shown in FIG. 12;

FIG. 14 is an elevation view, partly broken away to show details of construction, of a combustion chamber for the engine shown in FIG. 1;

FIG. 15 is a fragmentary plan view taken along the line and in the direction indicated by the arrows **15—15** in FIG. 14;

FIGS. 16 and 17 are fragmentary views taken along the lines and in the directions indicated by the arrows **16—16** and **17—17** in FIG. 14;

FIG. 18 is a fragmentary elevation view of a turbine inlet nozzle mounting arrangement used in the engine shown in FIG. 1;

FIG. 19 is a fragmentary elevation view showing an alternate insulation embodiment of the arrangement of FIG. 18;

FIG. 20 is a plan view of the lubricating oil circuit for the engine shown in FIG. 1; and

FIG. 21 is an elevation view of the lubricating oil circuit shown in FIG. 20.

An enclosure for a gas turbine engine and electric generator set constructed in accordance with one embodiment of the present invention is indicated generally by the reference numeral **31** in FIGS. 1 and 4.

The entire enclosure **31** and all of its components are built upon a base **32**. The gas turbine engine, indicated generally by reference numeral **33**, and the electric generator **34** are mounted directly to the base **32**.

The gas turbine engine **33** includes an inlet housing **36**, described in greater detail below with reference to FIGS. 7, 8 and 9 and a centrifugal compressor **37** (see FIG. 1).

The air from the compressor is fed to a combustion chamber **38**. The combustion chamber **38** includes an igniter **39**, a fuel nozzle and flow divider **41**, described in greater detail below with reference to FIGS. 10 through 13, and a liner **42**, shown in detail in FIG. 14.

The outlet of the combustion chamber **38** is connected to a scroll **43**. The scroll **43** directs the combustion gases to a turbine inlet nozzle assembly **44** and to a two-stage turbine wheel **46**.

The exhaust gases leave the turbine through an exhaust duct **47** and exit from the enclosure **31** through an exhaust opening **48**.

The turbine **46** drives the compressor **37** through a drive shaft **49** which is mounted for rotation in the main or bearing frame **51** of the engine **33**.

The drive shaft **49** is also effective to drive the generator **34** through a long flexible quill shaft **52** and speed reduction gearing **53**. Though not illustrated as such, the reduction gearing **53** may preferably include triaxial bevel drive gearing, and any one of four, or more, desired speed reductions may be obtained by changing the design parameters of one gear set in the reduction gearing **53**.

The long flexible quill shaft permits some self-adjustment of the shaft to compensate for misalignment of the gas turbine engine axis and the gear case input axis.

The output shaft of the reduction gearing **53** is connected to drive the generator **34**. One form of the reduction gearing **53** reduces the output speed of the engine from 28,800 r.p.m. to an 1800 r.p.m. drive speed for the generator **34**. As noted above, generator drive speeds of 2400, 3000 and 3600 r.p.m. can be obtained by minimum modification of the reduction gearing.

A blower **56** is also mounted for drive by the output shaft of the gearing **53**, and this blower **56** forms an important element in a system for circulating cooling and ventilating air and which will now be described.

The enclosure **31** incorporates a cooling and ventilating arrangement which is effective to provide all of the cooling and to provide all of the ventilation required for safe operation without the need to resort to auxiliary external conduits or other structure. The cooling air is drawn in from the left-hand end of the generator **34** as viewed in FIGS. 1 and 4 through an opening which is not shown in the drawings. The cooling air flows over the generator and then is forced downwardly by the fan **56** to a cooling air duct **57** formed in the base **32**. Turning vanes **58** turn the air upwardly, after it has passed along the underside of a sump **59** for the lubricating oil of the engine, and direct the air through an air-oil heat exchanger **61**. The air-oil heat exchanger is in the engine lubricating oil circuit, which includes a pump **55** and filters **60** (see also FIGS. 20 and 21), and the air circulated through the heat exchanger **61** cools the oil before it is returned to the engine. The oil in the sump is additionally cooled by the flow of cooling air along the underside of the sump.

After the air passes through the heat exchanger **61** it is circulated past the outside of the gas turbine engine **33**, as shown by the flow arrows where it serves to limit the temperature of the air in the enclosure to about 200° F. and also to remove any fumes that might leak from the gas turbine engine to the interior of the enclosure **31**. The air is then exhausted from the enclosure **31** through louvers **50** as shown in FIG. 4. The separate hot engine exhaust may be directed to a boiler or other heat recovery system.

An alternate exhaust duct arrangement is shown in FIG. 5. In this arrangement the cooling air flow is introduced into the engine exhaust through a generally funnel-shaped member **62**. In this arrangement the engine exhaust aspirates the cooling air flow and the combined exhaust is then turned through a ninety degree angle by the elbow **63**. The cooling air flow reduces the temperature of the engine exhaust gases and eliminates the need for costly stainless steel exhaust ducting. The exhaust elbow **63** is preferably provided with sound insulation blankets on its walls. This insulation plus the right-angle bend reduces the exhaust noise to an acceptable level.

All controls for the gas turbine engine generator set are contained in the control console **66**.

The enclosure **31**, as noted above, contains all of the engine noise silencing and inlet air filtering required for installation and operation of the engine. The inlet silencing is provided by ducting which turns the incoming air through a series of right-angle turns, and against acoustical insulating material on some of the walls of the duct, to reduce the noise of the engine compressor to an unobjectionable level. Each right-angle bend reduces the noise transmission by approximately 7 to 10 decibels. In the enclosure **31** six right-angle bends are provided in combination with four air filters as will now be described.

With particular reference now to FIGS. 2, 3, and 6, the air for the gas turbine engine is brought into the enclosure **31** through a circular opening **67** in the top wall of the enclosure. The incoming air is immediately divided into two flow paths and turned through a first ninety degree bend by an inner ceiling **68**. The air at this point flows in both a leftward direction and in a rightward direction as viewed in FIG. 2. For convenience of description only the continued flow of the leftwardly flowing air will be described. The structure which conducts the rightwardly flowing air to the engine is identical to that which will be described for the leftwardly flowing air.

After being turned ninety degrees by the inner ceiling **68** the air is again turned ninety degrees to a downward direction by the inner surface of an excess panel **69**. The air is subsequently turned through another ninety degrees and caused to pass through two air filters **71** as it is divided into two streams by a vertically extending wall **70** (see FIG. 3) after it passes through the filters.

The surfaces of the ceiling **68** and the access panels **69** are preferably coated with an acoustical material for silencing the compressor noise. Also, the panels **69** are disposed directly opposite the filters **71** so that the panels can be removed for access to the filters **71**.

The air then passes through ports **72** (see FIG. 3) and into a longitudinally extending channel **73**. In doing so the air is again turned through a right angle. At the outlet end of the channel **73** the air passes through ports **74**, as it is turned through a ninety degree angle and into a chamber **76**. The air is again turned through a ninety degree angle as it passes from the chamber **76** to the inlet of the compressor inlet housing **36**.

The center-to-center distances between the ports **72** and **74** in each of the flow channels on either side of the dividing wall **70** are approximately equal to provide a balanced volume of air flow.

The compressor inlet housing **36** is specially shaped to produce a compact inlet housing which is easy to manufacture but which is highly efficient and effective to prevent turbulence and separation while providing uniform

air flow at the compressor inlet. In order to turn the air flow so that a uniform flow occurs about the entire circumference of the compressor inlet, while retaining the feature of both axial and radial compactness, the walls of the inlet housing must be contoured to some shape other than a conventional rectangular or a U-shaped inlet. Such conventional inlets suffer the deficiencies of nonuniform flow, turbulence and fluid separation.

With reference now to FIGS. 7, 8 and 9, and particularly to FIG. 7, the inlet housing **36** is symmetric about a vertical plane passing through the center of reinforcing strut **81** at the inlet end of the housing and the axis of rotation AX of the compressor. The inlet contains a flared wall **80** which acts to accelerate and smooth the entry flow.

The inlet housing further comprises two distinct regions for handling the incoming air flow.

The first region is defined by the lower curved portions of the sidewalls **82** and functions to turn the incoming air through various angles up to an angle of 180° from a vertical direction to substantially symmetric flow in a radial direction with respect to the axis of rotation AX.

The second region is defined in part by the curved portions of the end walls **83** and **84** (see FIG. 8) and functions to turn the air from a radial direction through ninety degrees to an axial direction while accelerating the flow. The line of division between the first region and the second region is the base circle **86** as shown in FIG. 7.

In the particular inlet housing shown in FIGS. 7, 8 and 9 the curved portions of the sidewalls **82** are formed as involutes of the base circle **86**. That is, each of these sidewalls corresponds to a curve traced by a point of a thread kept taut as it is wound upon or unwound from the base circle with one end of the thread fixed to the point indicated by the reference numeral **87** in FIG. 7 at the intersection of the base circle **86** and the vertical plane passing through the axis AX.

This contoured wall configuration would produce a direction of flow which would be perpendicular to the base circle at all points on the base circle if the fluid were incompressible. While the incoming air is compressible, the curvature of the sidewalls **82** is effective to produce substantially the same results as if the incoming fluid were incompressible, and this curvature is thus effective to cause all parts of the incoming air flow to move in the desired direction without turbulence, separation and nonuniform flow.

While the involute shape described has several advantages from the standpoint of ease of manufacture, other geometric forms could be utilized. It is necessary that the geometric form selected start at the approximate level of the top of the base circle **86**, droop below the bottom of the base circle and terminate at approximately the bottom of the base circle in a symmetrical relationship with a vertically oriented axial plane.

The flow divider and fuel nozzle **41** for the gas turbine engine **33** is shown in more detail in FIGS. 10 through 13. FIGS. 10 and 11 show the construction used for liquid fuel, and FIGS. 12 and 13 show the construction used for gaseous fuel.

In the case of the liquid fuel nozzle the primary fuel flow is through line **89** and the secondary flow is through line **88**. A solenoid controlled valve **90** is electrically actuated by a speed switch to control the position of the valve.

The fuel nozzle **41** for the gaseous fuel has a series of orifices **95** extending perpendicularly to the conical lower end of the nozzle to produce intimate mixing of the gas with the incoming swirl of air produced by the swirler vanes **96** at the top of the liner **42**.

The combustion chamber **38** incorporates a liner **42** which, as best shown in FIG. 14, is of a two-part construction. The liner **42** has an upper dome-shaped section **101** and a lower cylindrical-shaped section **102**. The dome is connected to the cylindrical section by a corrugated strip **103** which allows cooling air from the air jacket around the liner to flow into the liner and along the inner surfaces of the cylindrical section **102**. Directing tubes **104** direct air radially inwardly a sufficient distance to aid combustion and to help eliminate hot spots which otherwise would be produced on the liner.

An upper cooling skirt **106** and a lower cooling skirt **107** direct air from the respective cooling holes **108** and **109** along the inner surfaces of the dome and the cylindrical section.

High temperatures and skirt expansion are less of a problem in the dome section than in the cylindrical section. As a consequence the skirt **106** can be spot-welded directly to the dome **101**. However, a rigid connection between the skirt **107** and the section **102** can cause distortion of the skirt **107**. This distortion can restrict some of the cooling air passages **110** (see FIG. 15) between the skirt and the liner, and result in inadequate cooling air flow and the formation of hot spots on the liner itself.

This problem of distortion was eliminated by providing a floating connection between the skirt **107** and the liner secton **102**.

Radially inwardly projecting pins **112** are suitably attached at one end, as by a tungsten inert gas puddle melt welding process, to the liner section **102**. The corrugated leading edge of the skirt **107** is supported on the inner ends of the pins **112**. This construction permits the leading edge of the skirt **107**, which generally runs somewhat hotter than the trailing edge, to expand and to contract without any physical restraint during temperature changes within the combustion chamber. As a result, the skirt does not distort and the skirt is at all times effective to direct the cooling air flow both upwardly and downwardly in the manner for which it is designed.

The liner **42** may also incorporate a plurality of circumferentially spaced fins **113** for preventing air swirl about the liner to thereby provide more uniform air entry for the cooling air admitted through the inlet holes.

The turbine inlet nozzle assembly is one component of the gas turbine engine which is subjected to large and rapid temperature changes during certain phases of operation of the gas turbine engine. The turbine nozzles must be retained in their operative position, but any excessive restraints on thermal growth can cause problems of distortion and cracking.

A turbine nozzle assembly construction and mounting arrangement which has been found effective to avoid problems of cracking is illustrated in FIG. 18.

The turbine nozzle assembly **44** includes a series of nozzles **116** mounted between an outer hoop **117** and an inner hoop **118**. The outer hoop **117** is connected to a similar hoop **119** for the second stage turbine nozzle and both parts are suspended in part by a flexible curved wall **121** of a scroll **43** which conducts the hot gases from the combustion chamber **38** to the nozzle assembly **44**. The opposite wall **122** of the scroll is preferably lined with insulation **123**, and a passageway **124** may also be provided beneath the insulation for circulating cooling air between the scroll and the main frame **51** of the gas turbine engine.

The lower hoop **118** is supported from the frame **51** by a cone-shaped member **126**. The cone-shaped member **126** is integral with the inner hoop at one end and is connected to the engine frame at the other end by a series of circumferentially spaced bolts **127**. The cone-shaped member **126** provides a thin-walled, generally axially extending section which is flexible enough to permit thermal expansion of the nozzle assembly components and to prevent restraining stresses that could cause cracking during the thermal growth produced by rapid increases in temperature in the different parts of the nozzle assembly.

A ring of insulation **128** is disposed in a recess formed in the frame **51** beneath the cone-shaped member **126**. This insulation ring is also mounted in position by the

bolts **127**. The insulation ring **128** and the cooling air passage **131** insulate the turbine bearing **129** mounted at the turbine end of the frame **51**.

The bolts **127** may be drilled to provide passageways **131** for conducting cooling air through the bolts and against the base of the adjacent turbine wheel **46**.

FIG. 19 illustrates a modified form of insulating the frame **51** from the hot products of combustion; wherein the insulation **123** is secured directly to the frame. Cooling air may be directed through passageway **132** and a series of ports **133** for cooling purposes.

We claim:

1. An enclosure for a gas turbine engine having a compressor, said enclosure comprising a base member on which the engine is mounted, top, side and end walls enclosing the engine and mounted on the base member, a single air inlet formed in the top wall, duct means for dividing the incoming air into two streams and turning each stream through a plurality of right-angle bends to silence the compressor noise, air filters extending across the duct means adjacent the sidewalls, and access panels in the sidewalls removable for providing access to the filters.

2. An enclosure as defined in claim **1** wherein each stream is turned through six right-angle turns defined by flat surfaces of said ducting between the air inlet in the top wall and the inlet housing of the engine compressor and wherein some of the flat surfaces are covered with an acoustical lining.

3. An enclosure as defined in claim **1** wherein the engine has a compressor inlet housing connected to the outlet of the duct means, and wherein the inlet housing includes first smoothly curved wall means in the form of dual symmetric geometric curved surfaces for turning the incoming air from a given direction across the axis of rotation of the compressor to symmetric converging flow in a radial direction with respect to the axis of rotation of the compressor and second smoothly curved wall means for turning the air through another ninety degrees to an axial direction while accelerating the flow.

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U.S. Cl. X.R.

55—276; 181—50; 230—233